

Natural and Triggered Lightning Launch Commit Criteria (LCC)

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Notes on Revisions

The following changes have been made to the LCC since they were initially recommended by the LAP in May 1998. The revisions are for clarification only.

1. In Criterion 3 there was an ambiguity in 3 (b) (3) (b) as to which (a) is being called out because there are two (a)'s in the rule. The clarification is to change "specified in (a) above" to "specified in (a) immediately above."
2. In Criterion 9 the figure has been changed to use the units of kV/m on the x-axis for consistency with the other criteria and absolute value signs were put around E_c in the x-axis label.
3. In Criterion 10 the phrase "precipitation particle" has been changed to "ice particle" because the definition of Precipitation in Section 11 was too broad for its use in this criterion.
4. In Section 11 the definition of Nontransparent was clarified by replacing "Opposite of Transparent" with "Translucent or Opaque" and changing the order of the sentences to better distinguish the definition from the note.

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I. Introduction

A committee known as the NASA/USAF Lightning Advisory Panel (LAP) was formed to recommend changes to the USAF and NASA lightning Launch Commit Criteria (LCC) for manned and unmanned space launches. The LAP also provides an independent scientific assessment of and advice on lightning-related issues to the KSC Weather Office, the 45th Weather Squadron, and the 30th Weather Squadron.

The objective of the lightning LCC is to minimize the hazards to integrated launch vehicles after launch from vehicle-triggered lightning, natural lightning, and electrification resulting from interactions with the environment during the ascent phase of the mission. The primary protection method is to hold (delay) the launch while a hazardous condition exists. We believe the best way to insure safety from atmospheric electricity hazards, and also to improve launch availability, is to use an instrumented aircraft in conjunction with a ground-based field mill network to measure the electric field environment and its time development along and near the flight path.

This report documents the lightning LCC recommendations made by the LAP in May 1998 and supersedes the recommendations made by the LAP (then known as the Peer Review Committee) in March 1994.¹

The members of the LAP are given in Table 1. The formal activities of the LAP leading to the May 1998 recommendations are listed in Table 2. The LCC recommended by the LAP in May 1998 are contained in Section II.

Table 1. Members of the NASA/USAF Lightning Advisory Panel (LAP)

Name	Title	Affiliation
Dr. Harry C. Koons	Distinguished Scientist	Space and Environment Technology Center The Aerospace Corporation
Dr. E. Philip Krider	Professor and Chair, Lightning Advisory Panel	Institute of Atmospheric Physics University of Arizona
Dr. W. David Rust	Chief, Mesoscale Research and Applications Division	NOAA/National Severe Storms Laboratory
Dr. Richard L. Walterscheid	Senior Scientist	Space and Environment Technology Center The Aerospace Corporation
Dr. John C. Willett	Physicist	Air Force Research Laboratory

¹ H. C. Koons and R. L. Walterscheid, "Lightning Launch Commit Criteria," Aerospace Report No. TR-95(5566)-1, The Aerospace Corporation, El Segundo, CA, 1 Feb 1996.

Table 2. Formal Activities of the Lightning Advisory Panel

Activity	Location	Date
Panel Meeting	The Aerospace Corp. El Segundo, CA	4 Feb 1997
Panel Meeting	University of Arizona Tucson, AZ	8-9 Jan 1998
Panel Meeting	Kennedy Space Center, FL	27-29 Apr 1998

II. Natural and Triggered Lightning Launch Commit Criteria (LCC)

The Launch Weather Team must have clear and convincing evidence that the following hazard avoidance criteria are not violated.

Even when these criteria are not violated, if any other hazardous condition exists, the Launch Weather Team will report the threat to the Launch Director. The Launch Director may HOLD at any time based on the instability of the weather.

1. Lightning

- (a) Do not launch for 30 minutes after any type of lightning occurs in a thunderstorm if the flight path will carry the vehicle within 10 NM of that thunderstorm.
- (b) Do not launch for 30 minutes after any type of lightning occurs within 10 NM of the flight path

unless:

- (1) The cloud that produced the lightning is not within 10 NM of the flight path;

and

- (2) There is at least one working field mill within 5 NM of each such lightning flash;

and

- (3) The absolute values of all electric field measurements at the surface within 5 NM of the flight path and at the mill(s) specified in (2) above have been less than 1000 V/m for 15 minutes.

Note:

- (i) Anvils are covered in Criterion 3.
- (ii) If a cumulus cloud remains 30 minutes after the last lightning occurs in a thunderstorm then Criterion 2 applies.

Definitions: Anvil, Electric Field Measurement at the Surface, Flight Path, Thunderstorm, Within

2. Cumulus Clouds

- (a) Do not launch if the flight path will carry the vehicle within 10 NM of any cumulus cloud with its cloud top higher than the -20 deg C level.
- (b) Do not launch if the flight path will carry the vehicle within 5 NM of any cumulus cloud with its cloud top higher than the -10 deg C level.
- (c) Do not launch if the flight path will carry the vehicle through any cumulus cloud with its cloud top higher than the -5 deg C level.
- (d) Do not launch if the flight path will carry the vehicle through any cumulus cloud with its cloud top between the +5 deg C and -5 deg C levels

unless:

- (1) The cloud is not producing precipitation;

and

- (2) The horizontal distance from the center of the cloud top to at least one working field mill is less than 2 NM;

and

- (3) All electric field measurements at the surface within 5 NM of the flight path and at the mill(s) specified in (2) above have been between -100 V/m and +500 V/m for 15 minutes.

Note: Cumulus clouds in Criterion 2 do not include altocumulus, cirrocumulus or stratocumulus.

Definitions: Cloud Top, Electric Field Measurement at the Surface, Flight Path, Precipitation, Within

3. Anvil Clouds

(a) Attached Anvils:

- (1) Do not launch if the flight path will carry the vehicle through nontransparent parts of attached anvil clouds.
- (2) Do not launch if the flight path will carry the vehicle within 5 NM of nontransparent parts of attached anvil clouds for the first 3 hours after the time of the last lightning discharge that occurs in the parent cloud or anvil cloud.
- (3) Do not launch if the flight path will carry the vehicle within 10 NM of nontransparent parts of attached anvil clouds for the first 30 minutes after the time of the last lightning discharge that occurs in the parent cloud or anvil cloud.

(b) Detached Anvils:

- (1) Do not launch if the flight path will carry the vehicle through nontransparent parts of a detached anvil cloud for the first 3 hours after the time that the anvil cloud is observed to have detached from the parent cloud.
- (2) Do not launch if the flight path will carry the vehicle through nontransparent parts of a detached anvil cloud for the first 4 hours after the time of the last lightning discharge that occurs in the detached anvil cloud.
- (3) Do not launch if the flight path will carry the vehicle within 5 NM of nontransparent parts of a detached anvil cloud for the first 3 hours after the time of the last lightning discharge that occurs in the parent cloud or anvil cloud before detachment or in the detached anvil cloud after detachment

unless

- (a) There is at least one working field mill within 5 NM of the detached anvil cloud;

and

- (b) The absolute values of all electric field measurements at the surface within 5 NM of the flight path and at the mill(s) specified in (a) immediately above have been less than 1000 V/m for 15 minutes;

and

- (c) The maximum radar return from any part of the detached anvil cloud within 5 NM of the flight path has been less than 10 dBZ for 15 minutes.

- (4) Do not launch if the flight path will carry the vehicle within 10 NM of nontransparent parts of a detached anvil cloud for the first 30 minutes after the time of the last lightning

discharge that occurs in the parent cloud or anvil cloud before detachment or in the detached anvil cloud after detachment.

Note: Detached anvil clouds are never considered *debris clouds*, nor are they covered by Criterion 4.

Definitions: Anvil, Debris Cloud, Electric Field Measurement at the Surface, Flight Path, Thunderstorm, Within

4. Debris Clouds

- (a) Do not launch if the flight path will carry the vehicle through any nontransparent parts of a debris cloud during the 3-hour period defined below.
- (b) Do not launch if the flight path will carry the vehicle within 5 NM of any nontransparent parts of a debris cloud during the 3-hour period defined below,
 - unless
 - (1) There is at least one working field mill within 5 NM of the debris cloud;
 - and
 - (2) The absolute values of all electric field measurements at the surface within 5 NM of the flight path and at the mill(s) specified in (1) above have been less than 1000 V/m for 15 minutes;
 - and
 - (3) The maximum radar return from any part of the debris cloud within 5 NM of the flight path has been less than 10 dBZ for 15 minutes.

The 3-hour period in a) and b) above begins at the time when the debris cloud is observed to have detached from the parent cloud or when the debris cloud is observed to have formed from the decay of the parent cloud top below the altitude of the -10 deg C level. The 3-hour period begins anew at the time of any lightning discharge that occurs in the debris cloud.

Definitions: Cloud Top, Debris Cloud, Electric Field Measurement at the Surface, Flight Path, Nontransparent, Within

5. Disturbed Weather

Do not launch if the flight path will carry the vehicle through any nontransparent clouds that are associated with a weather disturbance having clouds that extend to altitudes at or above the 0 deg C level and contain moderate or greater precipitation or a radar bright band or other evidence of melting precipitation within 5 NM of the flight path.

Definitions: Associated, Flight Path, Nontransparent, Weather Disturbance, Within, Moderate Precipitation

6. Thick Cloud Layers

Do not launch if the flight path will carry the vehicle through nontransparent parts of a cloud layer that is

- (1) Greater than 4,500 ft thick and any part of the cloud layer along the flight path is located between the 0 deg C and the -20 deg C levels;
or
- (2) Connected to a cloud layer that, within 5 NM of the flight path, is greater than 4,500 ft thick and has any part located between the 0 deg C and the -20 deg C levels;

unless the cloud layer is a cirriform cloud that has never been associated with convective clouds, is located entirely at temperatures of -15 deg C or colder, and shows no evidence of containing liquid water (e.g., aircraft icing).

Definitions: Associated, Cloud Layer, Flight Path, Nontransparent

7. Smoke Plumes

Do not launch if the flight path will carry the vehicle through any cumulus cloud that has developed from a smoke plume while the cloud is attached to the smoke plume, or for the first 60 minutes after the cumulus cloud is observed to have detached from the smoke plume.

Note: Cumulus clouds that have formed above a fire but have been detached from the smoke plume for more than 60 minutes are considered *cumulus clouds* and are covered in Criterion 2.

Definitions: Flight Path

8. Surface Electric Fields

- (a) Do not launch for 15 minutes after the absolute value of any electric field measurement at the surface within 5 NM of the flight path has been greater than 1500 V/m.
- (b) Do not launch for 15 minutes after the absolute value of any electric field measurement at the surface within 5 NM of the flight path has been greater than 1000 V/m
 - unless:
 - (1) All clouds within 10 NM of the flight path are transparent;
 - or
 - (2) All nontransparent clouds within 10 NM of the flight path have cloud tops below the +5 deg C level and have not been part of convective clouds with cloud tops above the -10 deg C level within the last 3 hours.

Notes:

- i) Electric field measurements at the surface are used to increase safety by detecting electric fields due to unforeseen or unrecognized hazards
- ii) For confirmed failure of one or more field mill sensors, the countdown and launch may continue.

Definitions: Cloud Top, Electric Field Measurement at the Surface, Flight Path, Nontransparent, Transparent, Within

9. Electric Fields Aloft

Criteria 3, 4, 5, 6, 7, and 8(b) need not be applied if, during the 15 minutes prior to launch time, the instantaneous electric field aloft, throughout the volume of air expected to be along the flight path, does not exceed E_c , where E_c is shown as a function of altitude in Figure 9-1.

Definitions: Flight Path, Electric Field Measurement Aloft

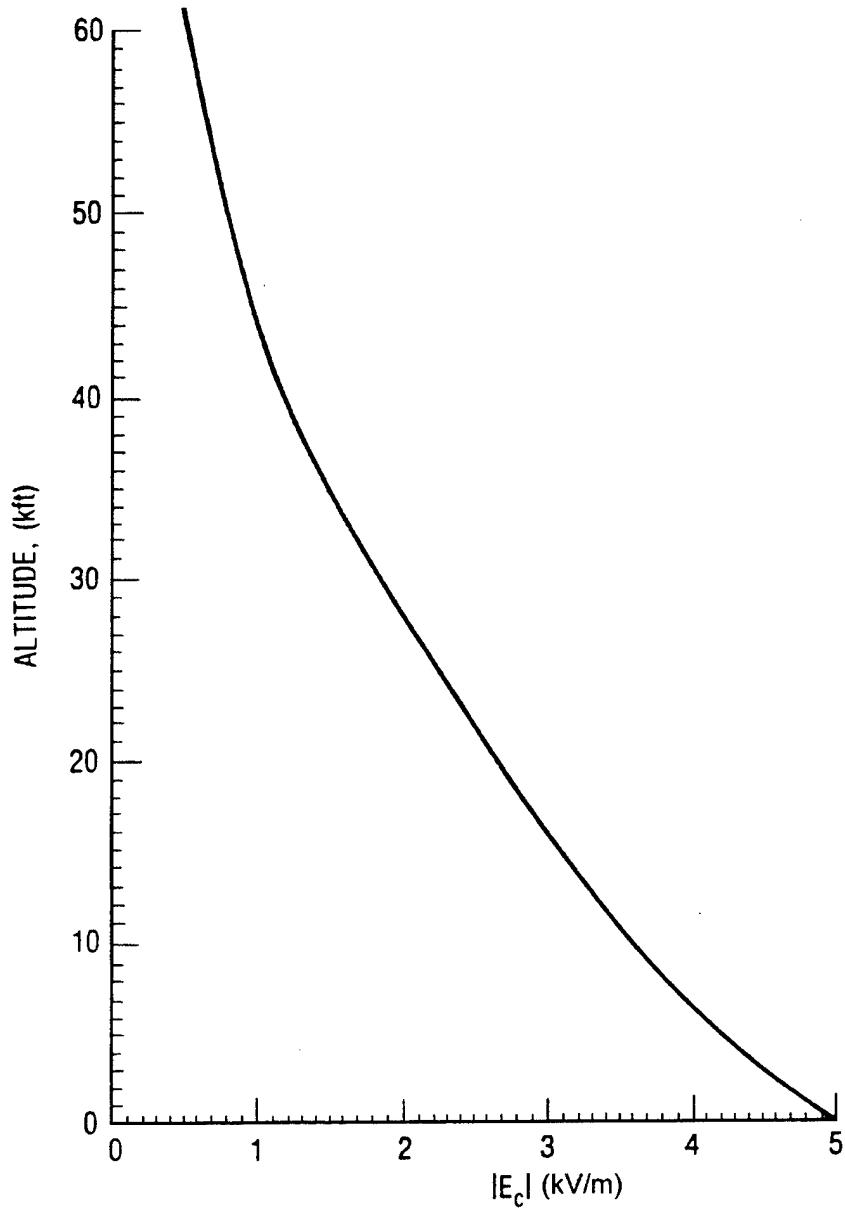


Figure 9-1. Instantaneous Critical Electric Field, E_c , vs. Altitude

Note: The thresholds on electric field measurements at the surface in Criterion 8 and elsewhere in these LCC are lower than 5 kV/m to allow for the effect of the surface screening layer.

10. Triboelectrification

Do not launch if a vehicle has not been treated for surface electrification and the flight path will go through any clouds above the -10 deg C level up to the altitude at which the vehicle's velocity exceeds 3000 ft/sec.

Note: A vehicle is considered "treated" for surface electrification if

- (a) All surfaces of the vehicle susceptible to ice particle impact have been treated to assure:
 - (1) That the surface resistivity is less than 10^9 ohms/square;
 - and
 - (2) That all conductors on surfaces (including dielectric surfaces that have been treated with conductive coatings) are bonded to the vehicle by a resistance that is less than 10^5 ohms;
- or
- (b) It has been shown by test or analysis that electrostatic discharges (ESD) on the surface of the vehicle caused by triboelectrification by ice particle impact will not be hazardous to the launch vehicle or the mission.

Definitions: Flight Path

11. Definitions:

Anvil: Stratiform or fibrous cloud produced by the upper level outflow or blow-off from thunderstorms or convective clouds.

Associated: Used to denote that two or more clouds are causally related to the same weather disturbance or are physically connected. *Associated* is not synonymous with occurring at the same time. An example of clouds that are *not* associated is air mass clouds formed by surface heating in the absence of organized lifting. Also, a cumulus cloud formed locally and a physically separated cirrus layer generated by a distant source are not associated, even if they occur over or near the launch site at the same time.

Subsidiary Definition: Weather Disturbance.

Bright Band: An enhancement of radar reflectivity caused by frozen hydrometeors falling through the 0 deg C level and beginning to melt.

Cloud Edge: The visible cloud edge is preferred. If this is not possible, then the 10 dBZ radar reflectivity cloud edge is acceptable.

Cloud Layer: A vertically continuous array of clouds, not necessarily of the same type, whose bases are approximately at the same level.

Cloud Top: The visible cloud top is preferred. If this is not possible, then the 10 dBZ radar reflectivity cloud top is acceptable.

Cumulonimbus Cloud: Any convective cloud with any part above the -20 deg C temperature level.

Debris Cloud: Any cloud, except an anvil cloud, that has become detached from a parent cumulonimbus cloud or thunderstorm, or that results from the decay of a parent cumulonimbus cloud or thunderstorm.

Subsidiary Definition: Cumulonimbus Cloud

Electric Field Measurement Aloft: The magnitude of the instantaneous, vector, electric field (**E**) at a known position in the atmosphere, such as measured by a suitably instrumented, calibrated, and located airborne-field-mill aircraft.

Electric Field Measurement at the Surface: The one-minute arithmetic average of the vertical electric field (E_z) at the ground measured by a ground-based field mill. The polarity of the electric field is the same as that of the potential gradient; that is, the polarity of the field at the ground is the same as the dominant charge overhead.

Note: Electric field contours shall not be used for the electric field measurement at the surface.

Flight Path: The planned flight path including its uncertainties (“error bounds”).

Moderate Precipitation : A precipitation rate of 0.1 inches/hr or a radar reflectivity factor of 30 dBZ.

Nontransparent: Translucent or opaque. Sky cover through which forms are blurred, indistinct, or obscured is nontransparent. Sky cover through which forms are seen distinctly *only* through breaks in the cloud cover is considered nontransparent. Clouds with a radar reflectivity of 10 dBZ or greater are also considered nontransparent.

Note: Nontransparency must be assessed for launch time.

Subsidiary Definition: Transparent

Optically Thin: Having a vertical optical thickness of unity or less at visible wavelengths.

Precipitation: Detectable rain, snow, sleet, etc. at the ground, or virga, or a radar reflectivity greater than 18 dBZ.

Transparent: Synonymous with optically thin. Sky cover is transparent if higher clouds, blue sky, stars, the disk of the sun, etc. can be distinctly seen from below, or if the sun casts distinct shadows of objects on the ground, or if terrain, buildings, lights on the ground, etc., can be distinctly seen from above.

Note: Visible transparency is required. Transparency must be assessed for launch time. Sky cover through which forms are seen distinctly *only* through breaks in the cloud cover is considered *non*transparent.

Subsidiary Definitions: Nontransparent, Optically Thin

Thunderstorm: Any convective cloud that produces lightning

Weather Disturbance: A weather system where dynamical processes destabilize the air on a scale larger than the individual clouds or cells. Examples of disturbances are fronts, troughs and squall lines.

Within: Used as a function word to specify a margin in all directions (horizontal, vertical, and slant separation) between the cloud edge or top and the flight path. For example, “*within* 10 NM of a thunderstorm cloud” means that there must be a 10 NM margin between every part of a thunderstorm cloud and the flight path.

Subsidiary Definitions: Cloud Edge, Cloud Top, Flight Path

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